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ON NOCTILUCENT CLOUDS

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Summary: This is an account of results of research of the noctilucent clouds during the last decades.

1. Introduction

From the esthetic standpoint, the noctilucent clouds (abbreviated LN) are undoubtedly one of the most beautiful manifestations which can be observed in the sky. Very often they can be observed as having an ice-blue coloration, an abundant interplay of shapes and forms, and a great variety of changes in brightness. Their appearance is somewhat similar to cirrus clouds, though they can be distinguished in the sky around twilight.

The first observation of LN in Europe was made in 1885. The German astronomer, Otto Jesse, should be mentioned especially for his significant research work. First investigations were also made at approximately the same time by Soviet researchers.

An intensive international investigation of these LN has not been made until recently. Though their occurrence was positively identified for more than a thousand times, there is to date, no acceptable explanation of this phenomenon.

It is strongly emphasized that observations of the LN by all countries are urgently desired.

2. Observational Facts

Some characteristics can be derived from the observations of the LN which are reported below.

A. Geographic Distribution

A frequency zone $\varphi = 50 - 70^{\circ}$ for both hemispheres could be assumed for the LN. Individual observations are also reported up to 45 and 80° N, but these would need further confirmation. The maximum frequency for both hemispheres lies approximately between 55 - 60°.

Observations made over a period of many years show that on the northern hemisphere the LN do not occur south of 45°. For instance, Astapovic reported that he could not see any LN in careful observations during 700 nights in Askhabad (37° N, 58°3 E).

An occurrence which has not been completely explained was pointed out by J. Paton. According to English observations, the frequency of the LN is displaced in a northerly direction during summer, that is that with increasing latitudes, the number of LN also increases. There is, up till now, no convincing physical interpretation for this polar displacement so that these questions must remain unexplained.

The diligent American expert, B. Fogle, submitted unambiguous proof for the occurrence of LN on the southern hemisphere. Due to the sporadic distribution of observers in the southern hemisphere it has not yet been possible to determine any unambiguous characteristics of the LN. Fogle's data, on the other hand seem to indicate that there is no difference in LN in either hemisphere.

B. Seasonal Frequencies

Up to now the LN were observed in the northern hemisphere between the fifth of March and the twenty-eighty of October. Some of the dates in March and October are uncertain. It is a question of whether the objects were actually LN.

On the northern hemisphere, the LN can be most frequently observed during the summer solstice during the month of July. The LN are most frequently seen during the months June - August while the frequency from March - May is considerably less.

It can be clearly seen from the American - English - German observations, that in the northern hemisphere the LN do not occur during the winter months.

C. Duration

Evidently LN cannot be observed during daytime. In August, 1963, two LN with a duration of 5 hours were observed in Alaska. In individual instances the repeated occurrence (during subsequent nights) of the LN can be substantiated. Very often the individual shapes of the LN appear and disappear within a period of a few minutes.

D. Circumstances for Movement

According to more recent observations, the preferred direction of movement of the LN is probably in the south-westerly direction, and the average velocity approximately 45 m/s. Individual measurements of up to 200 m/s were reported.

The wave nature of the LN is especially conspicuous. German and American measurements show wave lengths between 7 and 100 km. The preferred wave length is approximately 10 km.

It is relatively difficult to measure the thickness of the LN. Witt determined it to be between 1 - 3 km, while Vasilyev gives values of 0.5 - 1 km. Roennebecker made determinations of the LN on the fourth of July, 1967, and obtained 1.7 - 2.5 km. The wave amplitude is reported by Witt to be 1.5 - 3 km, while Vasilyev noted values between 1 ÷ 5 km.

Numerous altitude determinations of the LN were made during the last decade. The average values amounted to 82 km; this value varies between 74 - 92 km.

E. Measurements of Particles

Polarization measurements were published, among others, by Witt, Villmann and Vasilyev. According to Witt, measurements of the particle diameter is approximately 0.3 μ. The first measurements of the diameters were made in 1962, in northern Sweden during rocket experiments. The results of these experiments indicate: a) the diameters range from 0.05 - 0.5 μ; b) a portion of the particle was covered with a layer of ice; c) it was suspected that the particles are of extraterrestrial origin; d) during the presence of LN, the particle density was higher by a factor of 1000 than in the absence of LN.

3. Theoretical Concepts

It is interesting to note that the LN are objects which had been, up to the present, observed and interpreted, but whose nature and origin there is even now, no agreement among the experts. We, therefore, intend to discuss in the following, the most important concepts.

A. Volcanic Relationships

After the eruption of Krakatoa in the Straits of Java in 1883, conspicuous twilight phenomena could be observed all over the world. Since the year 1885, LN were observed in Central Europe.

It was assumed soon after this, that there is a possible connection between the LN and volcanic eruption. This opinion was supported after the following volcanic eruptions: Katmai (1912), Chile (1921), Japan (19231/32) and Quizapa (1932).

The suggestion of an existence of a relationship between the occurrence between the LN and volcanic eruptions was already rejected by V. Malzev in 1926. In particular it was shown that the LN could also be observed after the volcanic material had descended.

B. Intrusions of Cosmic Dust

Several authors (E. Hoffmeister, C. Stoermer) think that the LN originate from intrusions of cosmic dust and that the material comes from the permanent flow of meteors.

Hoffmeister, in particular, presented a model of circulation which supposed to interpret the dependence of the LN. A prerequisite for the occurrence of the LN would be the existence of a stable layer of dust; the presence of any vertical currents and turbulence would only destroy these layers, which also could explain the sporadic frequency of the LN.

No further literature on the Hoffmeister interpretation is presently available.

The experiments in the year 1962 seemed to support the theory of extraterrestrial contribution to the structure of the LN. An analysis with an electron microscope made at that time showed, that only a weakly defined structure surrounding the particles could be recognized.

Only after an exposure to evaporized chrome some particles indicated the presence of a halo. This pattern was assumed to be the consequence of an interaction with a volatile material (cosmic particles). The particles had a diameter of approximately 0.5 - 0.8 μ. Skrivanek recently presented an interpretation, according to which the particles in the halo contained relatively large quantities of sulfa and silicones along with the detection of small amounts of iron and calcium.

Recent measurements further indicate that in individual cases, some particles were actually detected which possibily could have a relationship to the LN. Nevertheless, all experiments should also be required to bring the opposite proof, that is, the absence of LN; generally speaking, a correlation with cosmic particles seems, at least, to be a possibility; but the empirical investigations still require comprehensive verification.

Furthermore, no mechanism has been found, up to now, which could explain the presence of particles at altitudes of 80 - 85 km.

Various authors (for instance, Glode) point out that individual currents of meteors should not have any secondary geophysical effects. We would also like to mention the studies by G. Kohl, McLone and H. Oleak; these authors discuss the behavior of meteors within the region of the atmosphere.

Taking everything into consideration, the question of the relationship to cosmis particles still needs intensive research before a definite statement is possible.

C. New Concepts

The physical behavior of the mesosphere has only been known for the last few years. Measurements have shown that there is a noticeable decrease in temperature during the summer months. On the other hand, during the winter months the mesosphere shows a much higher temperature profile.

Some direct measurements were obtained on the LN (Witt et al). In the presence of the LN a temperature of 130° K was measured, while in their absence a temperature of 140° K was obtained.

It has recently been reported that LN could also be observed in the absence of low temperatures. From this it would follow that low temperatures are a necessary but by no means sufficient prerequisite for the formation of LN.

For the time being it is significant that LN appear exclusively during a period of cold mesosphere; during winter, that is when the temperature of the mesosphere is higher, no LN have been observed up till now.

This state of affairs explained if we consider the relationship between mesospheric circulation and the frequency of LN. Schroeder found that the continuous observation periods for LN are limited by the change of direction of air currents in the mesosphere occurring during spring and fall. If we now start with the assumption that these changes need a certain amount of time it becomes understandable why LN appear outside of these defined periods (which in actuality can never be accurately defined). During this transition period it is quite possible that the circulation reaches up to 80 km and that sporadic formation of LN occurs.

Additional concepts, especially the ice hypotheses were published by the Russian researcher, I. A. Chvostikov, who recently died, as well as by E. Hesstvedt. The question, how water vapor could reach such altitudes has been explained by Chapman and Kendall by turbulence phenomena, while Charlson explains it by convection.

The ice-cloud model was treated in great detail by E. Hesstvedt. He investigated the question whether condensation or sublimation occurs. There are no objections to sublimation. Furthermore, it was shown that a nucleus with an initial size of 0.05 - 0.1 μ can grow, within a period of two hours. For the observed particle diameter of approximately 0.1 μ, a mixing ratio of 10^{-5} g/g is necessary.

G. Witt recently made a very interesting suggestion. According to this, the Fe-ions, found at an altitude of 80 km, form the nuclei of condensation which then grow by means of water deposition to approximately 0.5 μ.

According to the above concepts, the principle sources of origin are, therefore, either the humidity conditions or the formation of condensation nuclei.

The above discussion indicated that the different opinions as to the nature and the origin of the LN are still in a state of flux; an unambiguous explanation could not yet be made. There seems to be a definite indication that the behavior of the mesosphere is an important influence.

4. Summary of Knowledge

Average altitude: 82.7 km.

Observation zone: 50 - 70° (N/S)

Observation period: March - September

Duration of LN: from a few minutes up to 5 hours.

Velocity: average value of 40 m/s in SW direction

Thickness: 0.5 - 2 km

Verticle Amplitude: 1.5 - 3 km

Particle Diameter: approximately 0.3 μ

Wave length: 5 - 100 km

Temperature in the Presence of LN: approximately 135° K

E. Final Remarks

The cooperation of all interested friends of nature and colleagues is required for any further observation and research of the LN. For instance, no positive reports have as yet been received from Austria; it would be very much appreciated if some observers would respond to this plea for cooperation.

Appendix

Observations of the LN should be predominately conducted during the months March - September in the northern hemisphere, September - March in the southern hemisphere. It is of basic importance to obtain even mere reports that LN were observed. It is desirable that the following also be reported:

1. date, location of observation with coordinates, observation time;
2. apparent location of the LN on the sky, altitude, azimuth as well as vertical extent;
3. data on brightness, 1 = weak, 5 = very bright;
4. appearance, I = diffused structure without particulars, II = bands, III = waves, IV = characteristic form, such as in the shape of a "vortex";
5. color.

It is also desirable to obtain photographs; they can be easily obtained with commercially available optics of 1:2.8 or better. It is recommended to use different exposure times and a sensitive film.

Whenever possible, a detailed description of the appearance should be included (especially morphological changes, interchange between waves and bands).

The author will appreciate any communication on this subject.

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